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Salahi, Arman; Dehghan, Ali Naghi; Sheikhzakariaee, Seyed Jamal; Davarpanah, Afshin

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Sand production control mechanisms during oil well production and construction

Arman Salahi [a], Ali Naghi Dehghan [b,**], Seyed Jamal Sheikhzakariaee [c], Afshin Davarpanah [d,*]

[a] Department of Petroleum and Chemical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
[b] Department of Mining Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
[c] Department of Geology, Faculty of Sciences, Islamic Azad University, Science and Research Branch, Tehran, Iran
[d] Department of Mathematics, Aberystwyth University, Aberystwyth, SY23 3BZ, UK

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ABSTRACT

Sand production is considered as one of the significant production issues that significantly reduce wellbore productivity. The process of sand or solids production in production operations is one of the crucial operational inefficiencies that can lead to wells collapsing. Besides, the drilling mud might erupt through the formation. Therefore, it is essential to properly determine what types of solids or sand are produced to correctly predict efficient sand control mechanisms. This paper aimed to compare different sand production control mechanisms and how to control or minimize sand production. Moreover, we consider injection pressure and sand moisture on the sand production rate. According to this study's findings, pressure injection and moisture increase had caused sand production increase, which should be considered in operational performances. Furthermore, chemical injection such as resin and hydrogel injection usually has efficient sand production control methods. An expandable sand screen is an expandable three-layer component that is driven into the well and expanded.

1. Introduction

Wellbore instability is considered to some known and unknown factors, which might affect the production operations (Bere and Kato, 2019; Chen et al., 2020; Cohen et al., 2019; Davarpanah and Mirshekari, 2019a; Dehghani, 2016; Garolera et al., 2019; Gholami et al., 2016). It is classified as controllable and uncontrollable issues (Davarpanah, 2020; Hu et al., 2020; Junmano et al., 2016; Rakhimzhanova et al., 2020; Salehi et al., 2019). The former classification is consisted of transient pore pressure, well inclination, erosion, and fluid-rock interaction (Davarpanah et al., 2018; Rabbani et al., 2018; Song et al., 2020; Speight, 2020; Sun et al., 2020; Tovar, 2018; Wang and Sharma, 2019; Yan et al., 2018). However, the second classification has mainly consisted of tectonic stresses, unconsolidated formations, natural faults and fractures, mobile formations, and higher in-situ stresses (Aghashahi Ardestani et al., 2019; Aroyehun et al., 2018; Bowes and Procter 1997; Davarpanah and Mirshekari 2019b; McLellan 1996; Mohiuddin et al., 2001). Determination of sand types would help production operations as some of the sands might be useful in the pore space cleaning. Typically, solids with an average size of 50–75 can provide a bearing solids load that should be controlled (Davarpanah et al., 2019; Davarpanah and Mirshekari, 2018; Zhu et al., 2020). The mechanism of sand production control is generally dragged force reduction and formation strength increase (Al-Awad and Desouky 1997; Al-Awad and Al-Misned 1997; Davarpanah and Nassabeh 2017; Dolui et al., 2016). Rahman et al. (2010) developed a decision-making flowchart to implement different criteria to select sand production control mechanisms. This is based on the passive sand production control and integrated geomechanical approaches. It is schematically shown in Fig. 1 (Rahman et al., 2010).

* Corresponding author.
** Corresponding author.
E-mail addresses: a.dehghan@srbiau.ac.ir (A.N. Dehghan), sheikhzakariaee@srbiau.ac.ir (S.J. Sheikhzakariaee), afd6@aber.ac.uk (A. Davarpanah).

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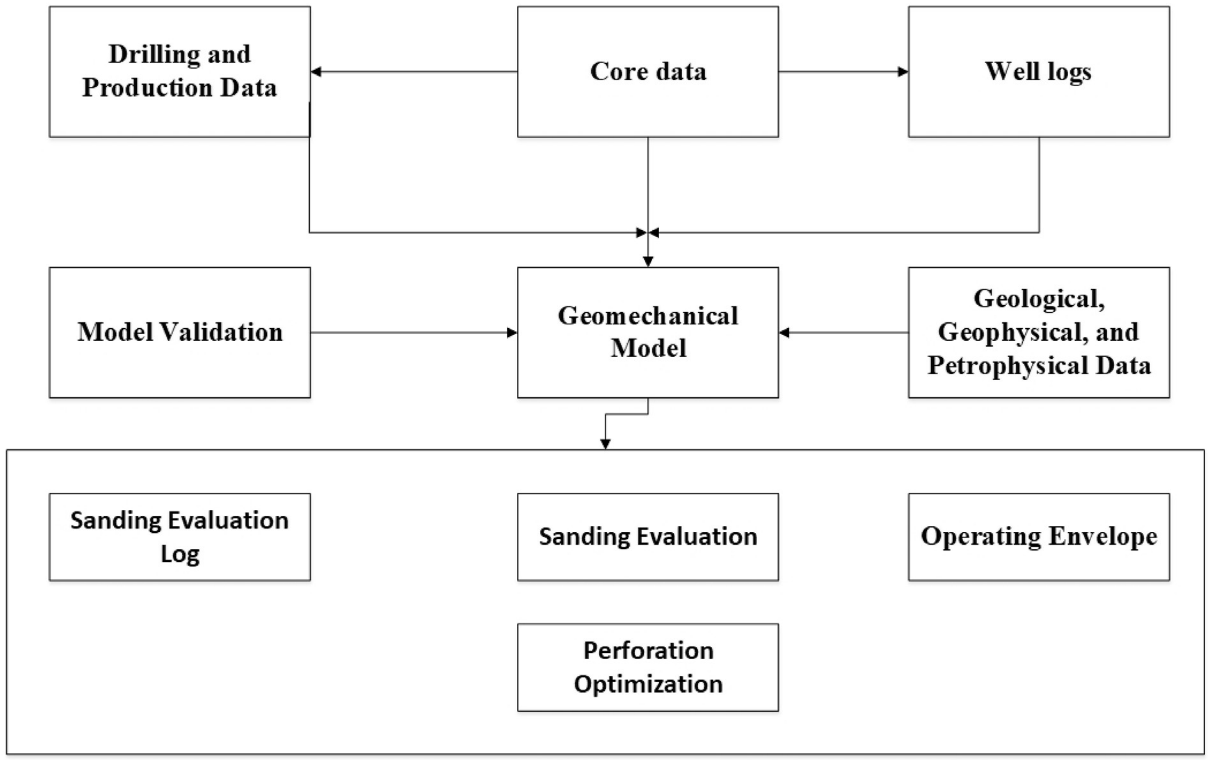

Fig. 1. Decision-making flowchart to implement different criteria in selecting sand production control mechanisms (Rahman et al., 2010).

To choose a suitable and practical way to control sand and determine its position in the well, it is necessary to know sand production mechanisms and which parameters affect its process. Discrete environmental methods are excellent tools for simulating sand production, especially for understanding the mechanism of sand formation. Before drilling, tight formations are in the hydro-mechanical equilibrium (static equilibrium of stress and porous pressure). However, drilling hydrocarbon reservoirs to produce oil and gas causes the redistribution of stress and perforation around the well. Therefore, sand particles are separated from each other and enter the well from the formation (Esmaeili 2018; Musa et al., 2017; Uchida et al., 2016). In the non-continuous structure (without adhesion resistance), the friction of the grains and their shape are two significant features in controlling the bulk's behavior. The shape of the grains and their internal friction both control the coefficient of internal friction and resist the final failure of the case. Fig. 2 shows the created gap just before sand production as a function of grain size and internal friction. The size of the grains has a critical control factor in the rate of sand production, although the aggregation performed consists of the same characteristics of the ball similar to the angled models in the two-axis tests. Spherical grains are about 8–4 times larger than the original product and have a higher stable production rate. Angled models with inter-granular friction amplitude show a typical decrease in sand production with the friction increase friction. Thereby, the reduction in sand production rate from the lowest to the highest amount is not a linear function of the inter-granular friction (Cerasi et al., 2005; Gago et al., 2020).

Shakiba et al. (2020) investigated that nanoparticles addition to the injected water might affect the sand shortcomings obviation. Injected nanoparticles would adsorb on the rock surfaces regarding the extremely small specific areas of their surfaces which can cover the surfaces of the rocks partially. This feature can be used as a prospective for unstable minerals during the low salinity water injection which can stabilize the interparticles and fine sand particles solidity (Shakiba et al., 2020). Roostaei et al. (2020) investigated the particle shape variation, fines' composition, and particle size distribution as a developed model to consider the sand production control. They used different sand sizes from micro sizes to major sand faces with the various coarsening impacts. They found that sand screen performance flow is controlled by slot apertures. Therefore, optimization the size of slots aperture would be used as a sand control mechanism during the presence of multiphase flow. Moreover, it can be concluded that pore plugging would be mitigated during this process (Roostaei et al., 2020).

In this paper, we aimed to consider different sand control mechanisms in operational performances and minimize the formation instabilities in these methods. As sands can affect operational performances during production engineering, functional designation process for efficient sand control methods can facilitate the completion processes which can be explicitly discussed in the following sections. Moreover, we set aside considering the profound impact of injection pressure and sand moisture on the sand production rate.

2. Sand control mechanisms

2.1. Sand control and management methods

The following methods control sand production: production rate control, mechanical sand control methods, chemical and control methods, and oriented perforation. One of the crucial factors influencing sand production was the mobility force during the fluid flow through porous media. To control this parameter or reduce its effect, fluid movement speed should be reduced, especially in the wellhead area. To do this, it needs to increase the effective cross-sectional area as much as possible, or in other words, reduce the speed of the fluid by increasing the diameter of the fluid flow path. This is usually the simplest, most effective, and cheapest way to

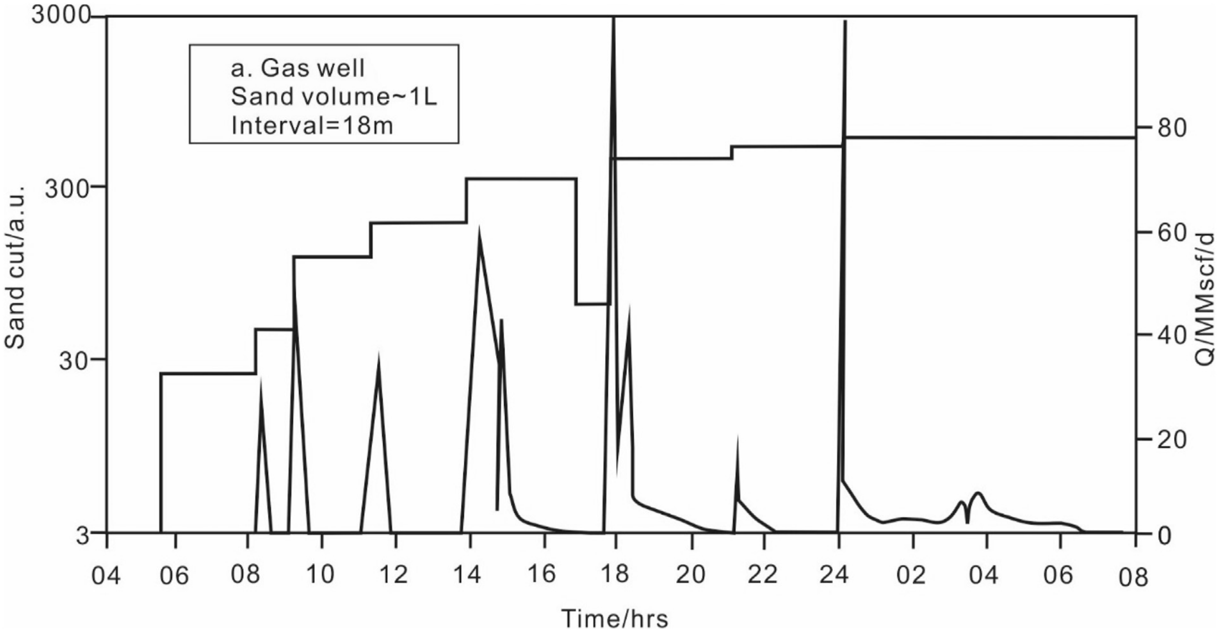

Fig. 2. Grain size effect in the transient sand production for different sand volumes (Khamehchi and Reisi 2015).

control sand if the oil production rate increases from a critical value, the production of sand increases dramatically (Daramola and Alinnor 2018; O'hara 2019).

2.2. Mechanical methods

To prevent sand production, fully latticed pipes were used that are placed in front of the production formation. Hence, only the fluid can pass through the mesh liner, and the sand particles cannot pass through the liner. Mechanical sand control is done in two ways. The first method is to use a liner or mesh without the filter. In this method, a liner is put in the well and front of the inlet fluid flow from the formation. Using any filter always does not cause a gap between the liner and the wall of the formation. This distance is the biggest problem when using unfiltered sleeves. In this distance, which is known as the circular area, sand particles cannot pass through the liner and settle down. Thereby, the liner is entirely closed, and production from the well is significantly reduced. The second mechanical sand control is the lattice liners (Dong et al., 2017; Ma et al., 2020).

2.3. Sand control using gravel pack

The Gravel pack controls sand production by placing filters of gravel grains that keep the sand grains in the filter. The optimal size of the gravel is proportional to the size of the grains in the sand. The Gravel pack is typically coiled and can be placed in wells with wall pipes or open wells. The gravel packing process involves cleaning the wellbore, which is placed in front of the production layer. The main factor in the production of controlled wells with Gravel pack is reducing the output fluid. The current limitation of this method also reduces permeability. Thus, the Gravel pack causes extra crusting and pressure drop (Khamehchi et al., 2015).

The gravel pack arrangement in the production wells is schematically depicted in Fig. 3 which is extracted from PCF software.

2.4. Expandable sand screen

As the world's oil companies complete their new drilling wells with this new method, this new method is called expandable sand screen (henceforth; ESS). ESS is an expandable three-layer component that is driven into the well and expanded. Its middle layer is called the Petra wave, which has had the main job of controlling the sand. The advantage of ESS rather than other methods is that it sticks completely to the inside wall of the well and completely eliminates the circular area after it expands. This solves all the problems of leaking wells as in other methods. After finishing the production operation, they create some space between them and the device. It stays and causes problems such as corrosion, erosion, and plugging. The advantages of the ESS method are as follows;

✓ *Reduce drilling costs;* ESS allows each well to be drilled to at least the size of a smaller wall pipe, which is why a drilling program with a smaller final diameter can be provided after drilling and completing the well. The desired diameter is obtained, which saves a lot of the total well cost.
✓ *Elimination of circular space;* as ESS sticks to the formation wall, it will remove the annulus space, which has caused to disconnect the fluid flow. Thereby, it comes into direct contact with the formation, while this area still exists in the gravel pack method. Even if it is completely removed, they will never be in direct contact with the formation.
✓ *Stability of the well wall and prevention of plugging;* as ESS adheres to the formation wall, it acts as a solid and can hold sand grains in place.
✓ *Preventing liner erosion;* ESS is in direct contact with the formation and removes the circular area that prevents the sand particles from being thrown towards the liner nets. On the other hand, because there is no blind spot in the ESS liner, so it minimizes the possibility of erosion (Matanovic et al., 2012).

3. Result and discussion

Sand stabilization is one of the chemical methods of sand control that injects fluid into the formation with cement to establish a bond between the grains of sand and cement and not to come out with the fluid during the production and extraction of sand oil. In

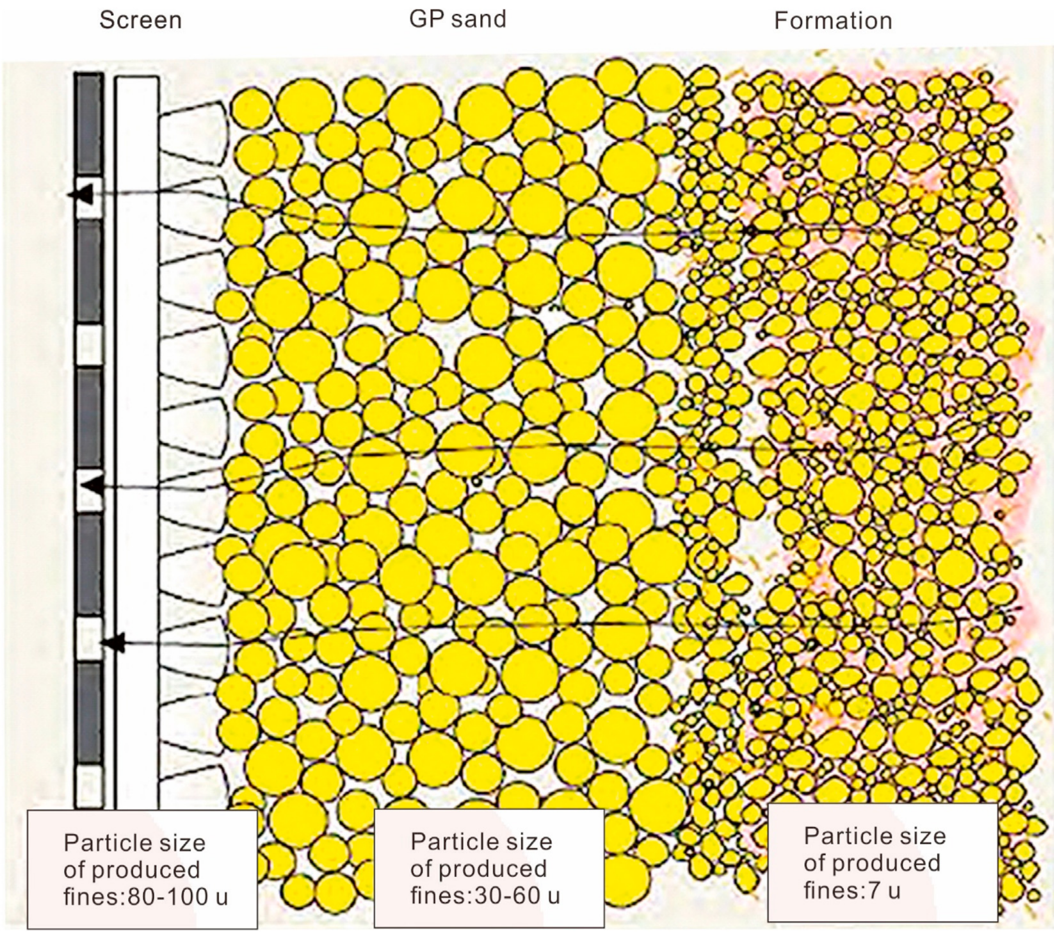

Fig. 3. Gravel pack arrangement in production wells which is extracted from PCF software.

this part of the study, different sand control methods and numerical solutions were discussed and compared.

3.1. Injection pressure impact

Operational factors are the strategies used to produce oil and gas, such as pressure difference, injection pressure, flow rate, and production rate. To investigate the effect of injection pressure on sand production, a series of tests were done on dry sands (zero humidity) with injection pressure variables of 150–200 KPa were performed. The results of these tests are shown in Fig. 4. As can be seen in Fig. 4, sand production increases with the increase of injection pressure. Yim et al. (1994) stated that current-induced drag forces affect sand arcs' stability in critical situations, which has increased by injection pressure rise (Yim 1994). According to the research of Clearley et al. (1979), the first layers of each formation have failed due to their dependency on the adhesive forces. Moreover, the characteristics of bridging and the redistribution of stress created by sand arcs are other crucial parameters. Therefore, the rate of sand production increases continuously by injection pressure rise according to the theory of Clearley et al. (1979) and Yim et al. (1994).

3.2. Sand moisture

To investigate the effect of moisture on sand production, some laboratory tests with an injection pressure of 180–150 kPa with different amounts of moisture (10%, 15%, and 20%) were performed. According to Fig. 5, the sand production rate is generally reduced by increasing the amount of moisture. According to research by Papamichos et al. (2001), sand production rates are related to the non-adhesion or adhesion of sand grains around the wellbores. As the saturation increases, the intermolecular uptake between the grains of sand increases due to capillaries. It may lead to an increase in the sand mass's adhesion and thus a decrease in the rate of sand production with increasing moisture. Therefore, according to Fig. 5, the sand production rate is significantly reduced by increasing the humidity from 10% to 15%, especially in 20% (Papamichos et al., 2001; Wiggs et al., 2004).

Many researchers have studied all sand control methods. According to the observed results, when the well is closed several times to make the requirements for testing or high series operations performed, the sand production rate increases. The mechanism that leads to an increase in sand production requires further investigation. The sample used is a relatively soft rock, measured with a single-axis compressive strength of 24.5 MPa and an estimated apparent adhesion resistance of 7.4 Mpa. The proportions of the sand volume produced in the initial production cycle when using water with 3.5% salt are used for the fluid pressure of 2, 1.25, and 0.5 MPa are 3.8%, 1.7%, and 0.5%, respectively. Higher amounts of sand are produced at high permeability fluid pressures due to the reduced pressure around the wellbore (Godinez-Brizuela and Niasar 2020; Zheng et al., 2020).

The formation of soft grains has been widely discussed in the literature by previous researchers. Zeitsu (1985) provided a concrete model that could be used for sandstone. He suggested that

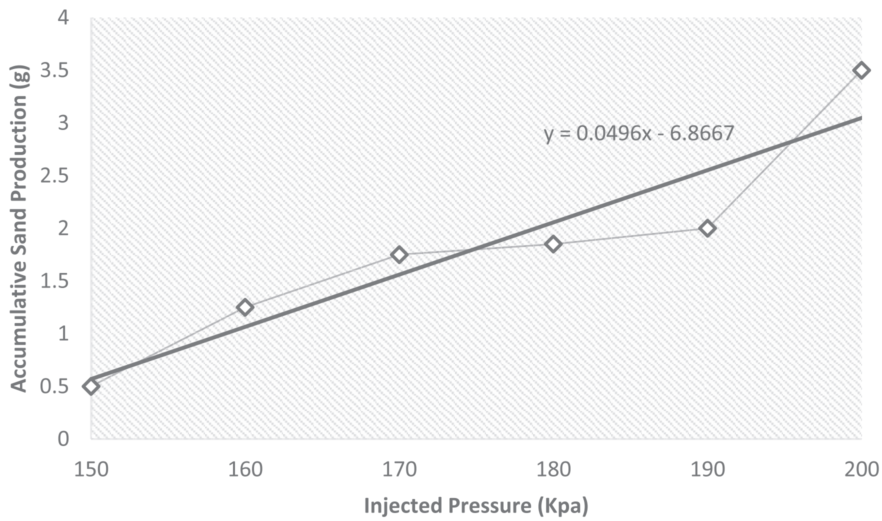

Fig. 4. Sand Production versus injected pressure.

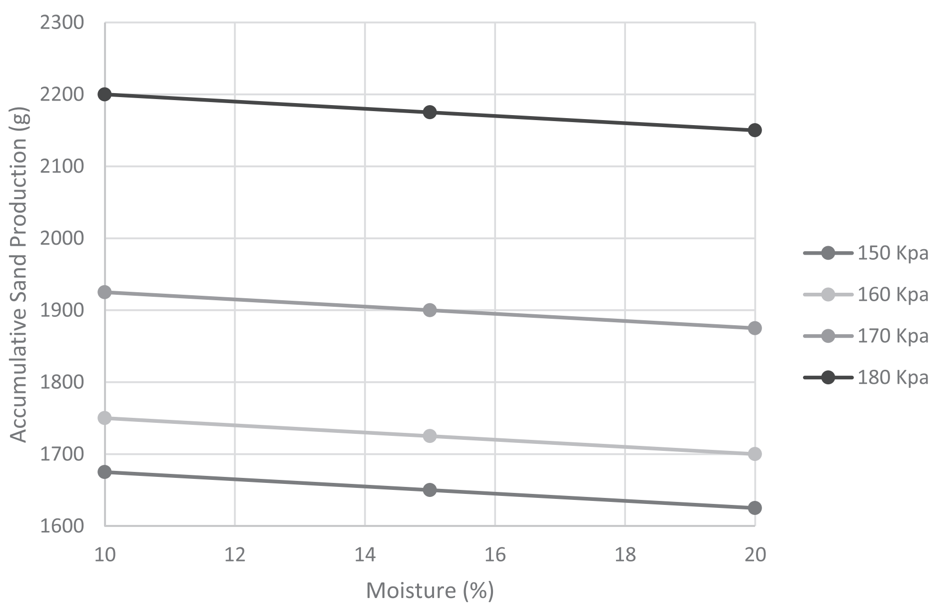

Fig. 5. Sand Production versus moisture for different injected pressure.

when there is a significant difference between the matrix and the grains' maturity, the micro-cracks are preferably developed in the matrix and can become blocks when they reach a grain. Two factors controlled the release of these micro-cracks; the difference between the grain size and the matrix and the micro-cracks, which are closed by the grains at the boundary. According to previous studies, the impact of minerals on sandstones' geomechanical properties is not clear, and in some cases, even completely unrelated results have been presented. For example, Bell and Lindsay (1999) found that UCS increased with increasing quartz levels in the sandstones of the Natal group in South Africa. They showed that increasing the amount of cement in sandstone leads to an increase in strength. Yulosai et al. (1994) obtained a similar result in Turkish Kozlan sandstones, showing that quartz grains' locking is more critical than the amount of quartz. One of the main factors controlling the strength of the stone is the lock between the grains and the cement content. It seems that where the cement bond between the grains is lost due to the spread of micro-cracks, the locking between the grains is the main factor in keeping the structure together.

Hodge et al. (2002) represented a new method to evaluate gravel-pack and screen-only completion to predict the produced solids value due to the stress increase. They concluded that formation particles amount would play a significant role in predicting produced solids (Hodge et al., 2002). Chemical injection, such as resin injection, usually has one of the efficient sand production control methods. Injectable resin should have the following characteristics; low injection pressure, created mass has an excellent compressive strength after the injection process and sand sticking, and the structure's permeability would not be significantly reduced. Therefore, high compressive strength is achieved when a thick resin coating is placed on the grains of sand, which reduces the permeability, and if the injection pressure is low, the resin should naturally coagulate. It has little viscosity, and this prevents high compressive strength. Some commercial materials used for resin injections include phenols, furans, and epoxy resins. Talaghat et al. (2009) prepared a special and suitable resin as a consolidating agent to control sand production in the Asmari oilfield. They investigated the considerable influence of six different types of resin. They are three types of phenol-formaldehyde, two types of epoxy, and one acrylic resin. They concluded that phenol-formaldehyde resin types would provide an acceptable porosity and permeability, and the compressive strength has increased rather than other resins (Talaghat et al., 2009).

4. Conclusion

The main conclusions of this study are as follows;

- Chemical injection such as resin and hydrogel injection usually has one of the efficient sand production control methods. An expandable sand screen is an expandable three-layer component that is driven into the well and expanded. It is preferred over gravel pack due to its better efficiency in sand control.
- Thin inner layers collapse and sand body collapse are the proposed model's primary failures when the drawdown pressure is lower than critical drawdown pressure.
- Phenol—formaldehyde resin types would provide an acceptable porosity, and permeability and the compressive strength has increased rather than other resins.
- The size of the grains has a critical control factor in the rate of sand production, although the aggregation performed consists of the same characteristics of the ball similar to the angled models in the two-axis tests.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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